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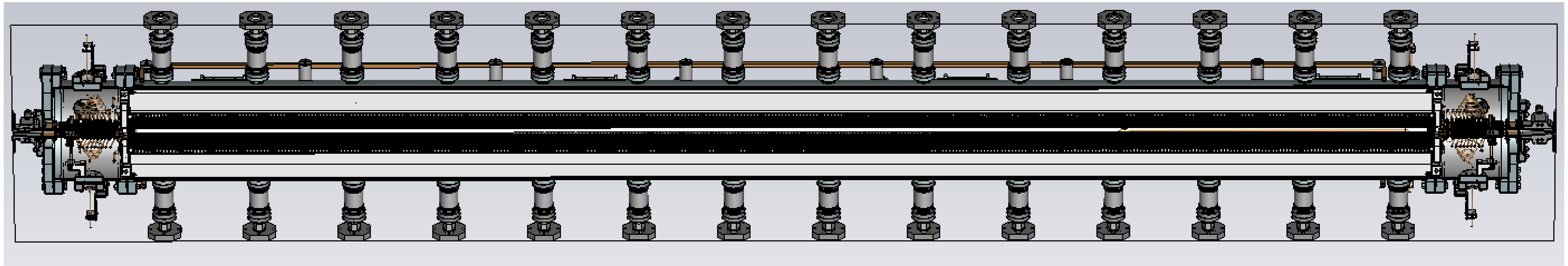
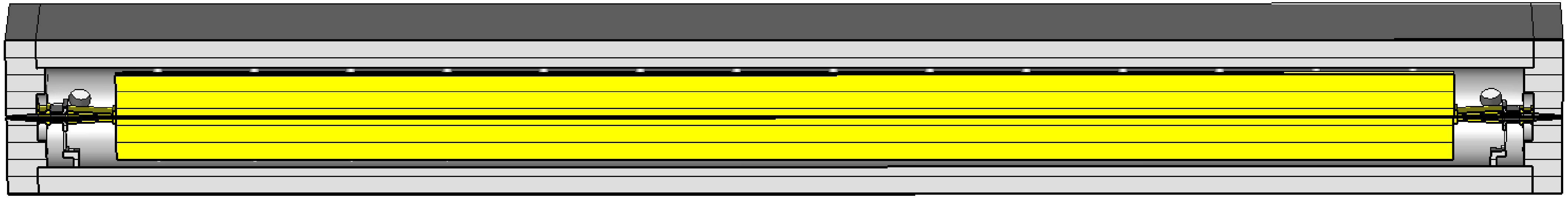
SHUNT IMPEDANCE SIMULATIONS FOR AN IVU AT PETRA-4

CONTENT

GEOMETRY



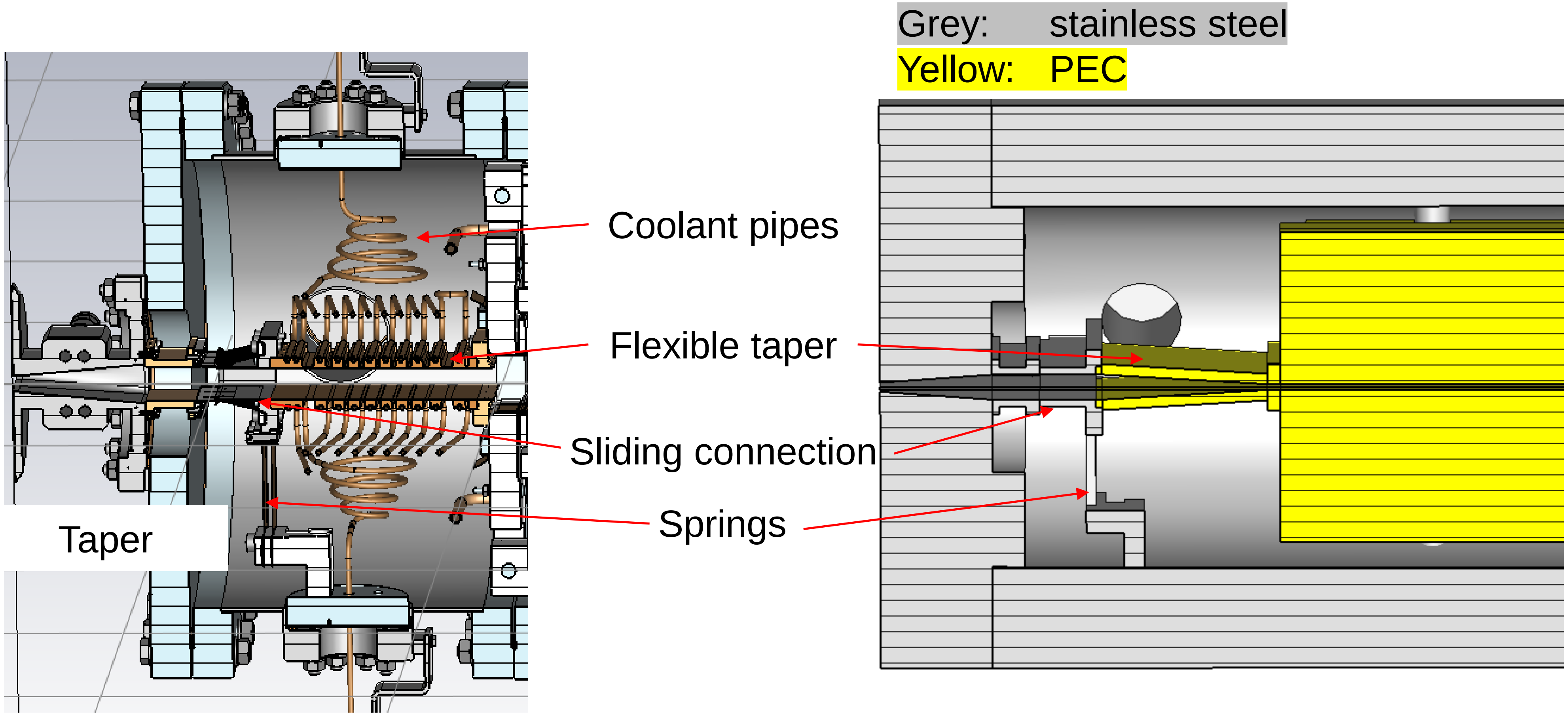


Entry Body Exit

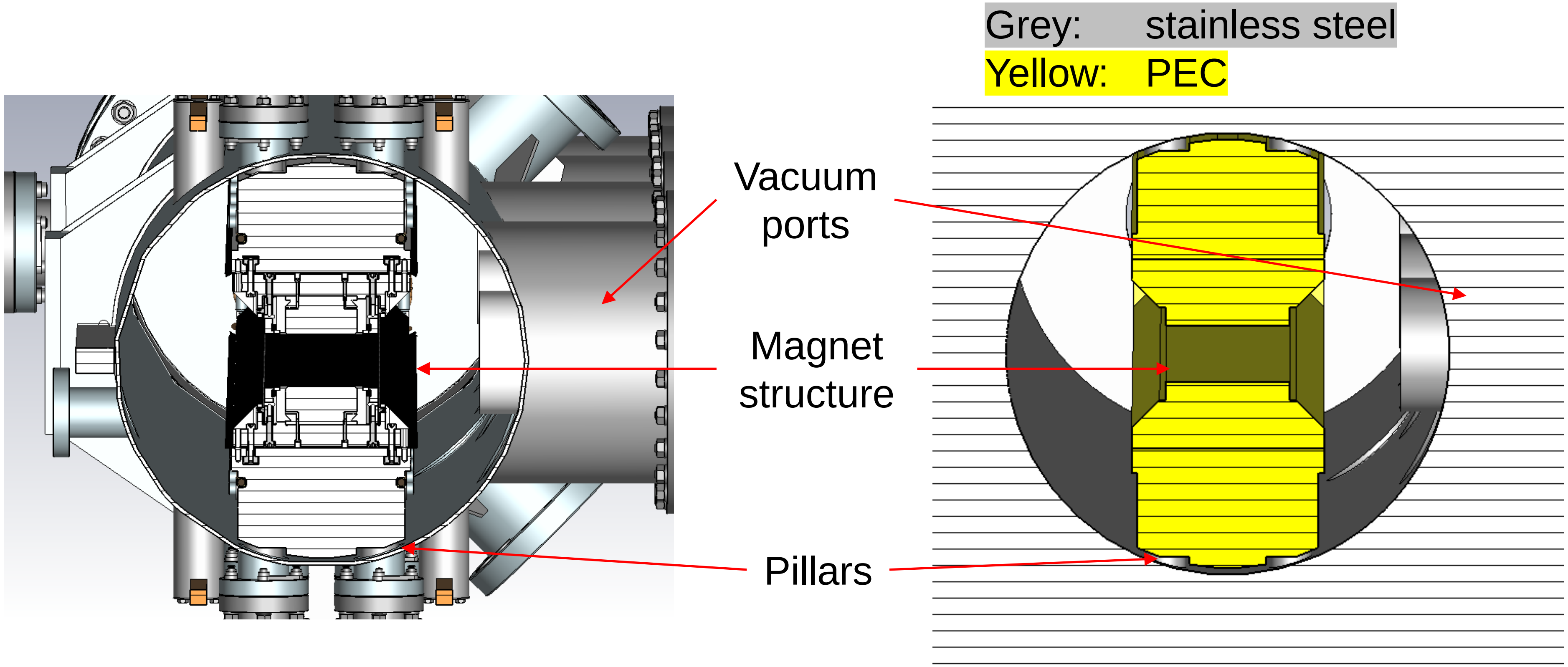
Grey: stainless steel 1.4e6 S/m

Yellow: PEC

GEOMETRY

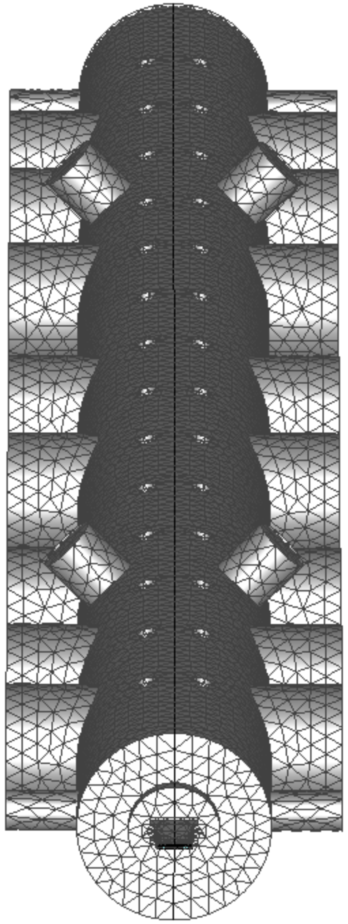

Grey: stainless steel
Yellow: PEC
Coolant pipes
Flexible taper
Sliding connection
Springs
Taper

GEOMETRY


Grey: stainless steel
Yellow: PEC
Vacuum ports
Magnet structure
Pillars

SIMULATION PROCEDURE

- Three independent solver
  - CST wakefield
  - CST eigenmode
  - FELIS (frequency domain impedance)
- Centered beam does not excite modes
  - Offset in horizontal direction has no impact
  - Small displacement in vertical direction (0.5mm)
- Model almost symmetric
  - Neglect cooling pipes
  - Mirror vacuum ports
  - Neglect small asymmetry in exit geometry



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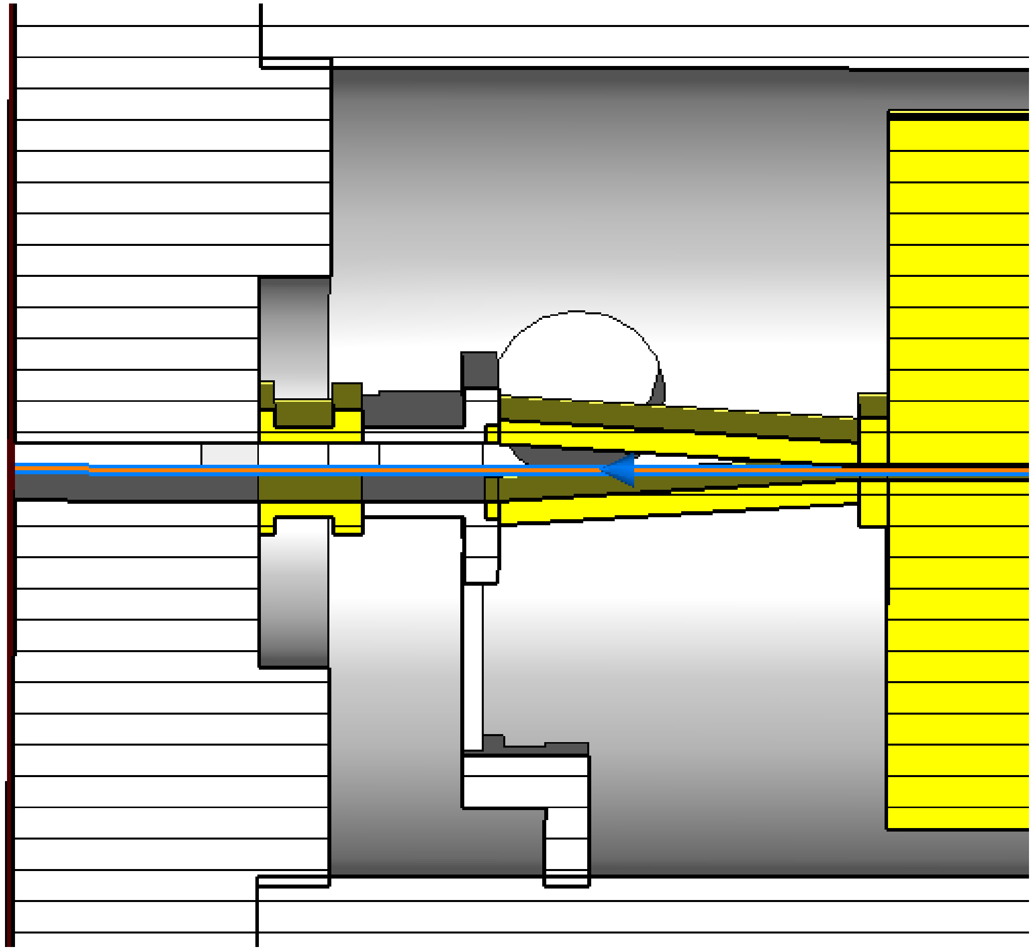
SIMULATION PROCEDURE

CST Wakefield Solver

- Geometry approximation
  - Entry taper simplied
    - Cutoff frequency ≈ 2 GHz
  - Mesh
    - Tapers
    - Tank
- Wake potential -> impedance
  - $\cos^2$ window
  - DFT
- Limitation: runtime



SIMULATION PROCEDURE

FELIS

- Impedance Solver in FD + FFS
- Geometry approximation
  - No additional simplification at entry/exit
  - 2nd order elements
- High order basis functions
- Materials
  - Only one surface impedance due to FFS
- Limitation: memory, (runtime)

SIMULATION PROCEDURE

FELIS

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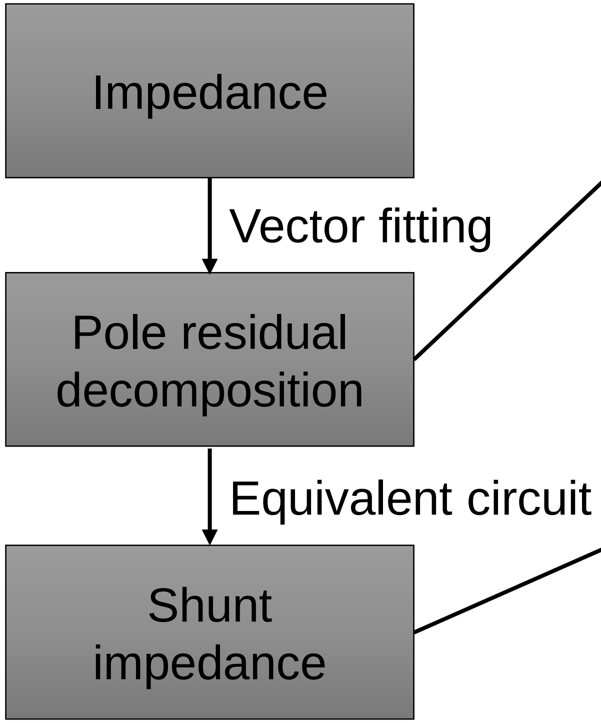
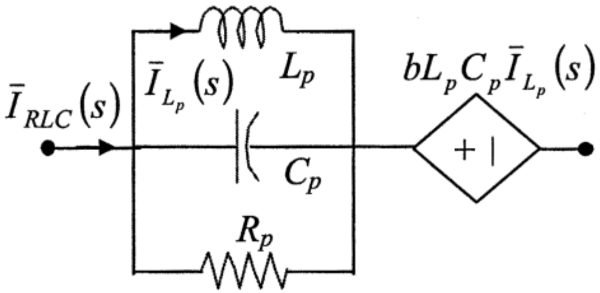


$$Z(\sigma) = d + \sigma e + \sum_{k=1}^{K} \frac{c_k}{\sigma - p_k}$$



Per mode

Giulio Antonini, *SPICE Equivalent Circuits of Frequency-Domain Responses*

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SIMULATION PROCEDURE

CST Eigenmode Solver

- No modes propagating in the beam pipes
  - Direct integration

$$V_i = \int_a^b E_{z,i}(z) e^{j\omega_i z/c_0} dz$$

- Longitudinal shunt impedances

$$R_{s,i} = \frac{|V_i|^2 Q_i}{2 W_i \omega_i}$$

- Limitation: memory

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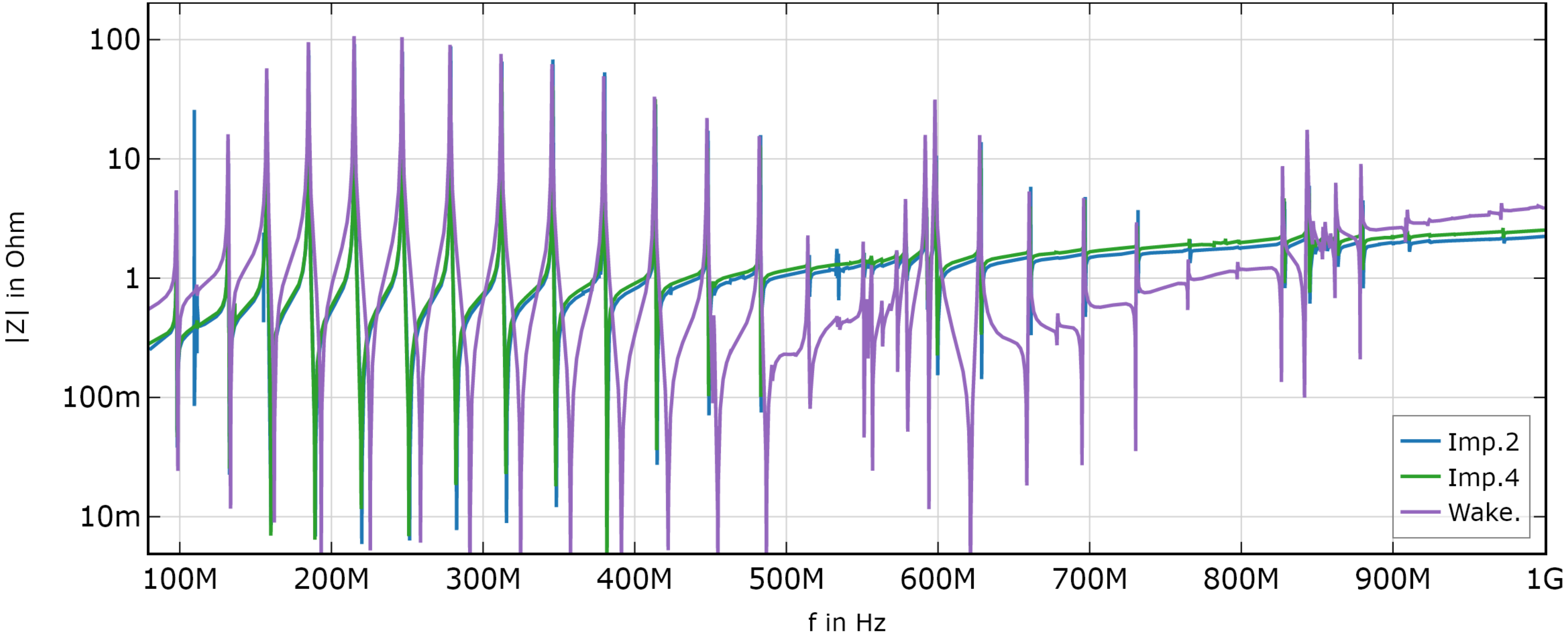
RESULTS

Impedances Comparison (PEC + steel)



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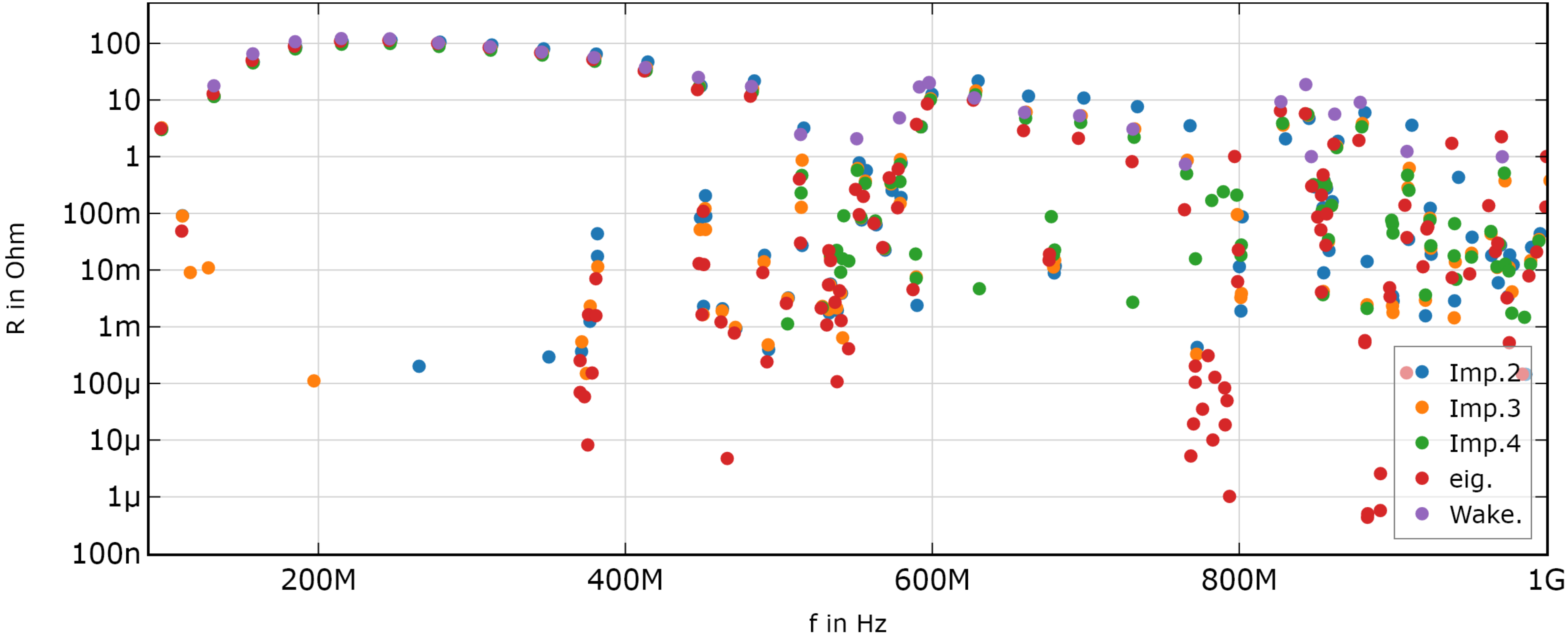
RESULTS

Shunt Impedances Comparison (PEC + steel)



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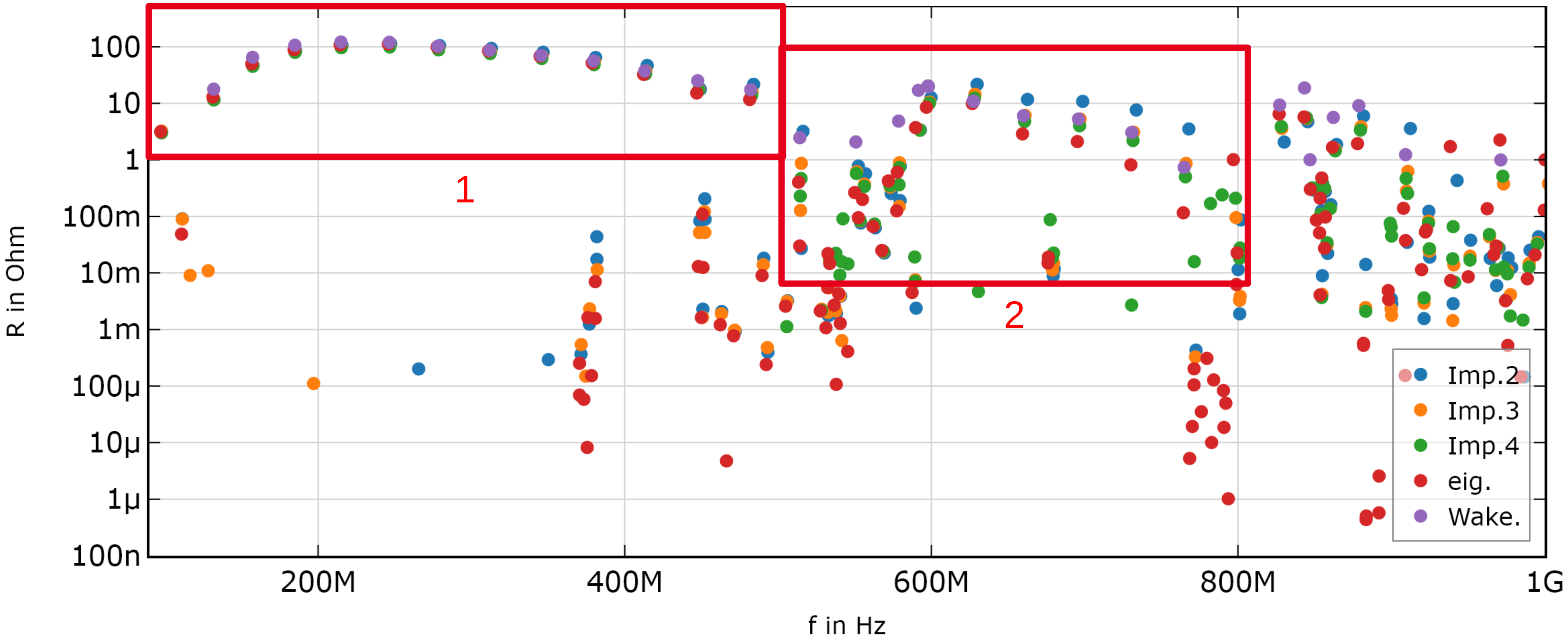

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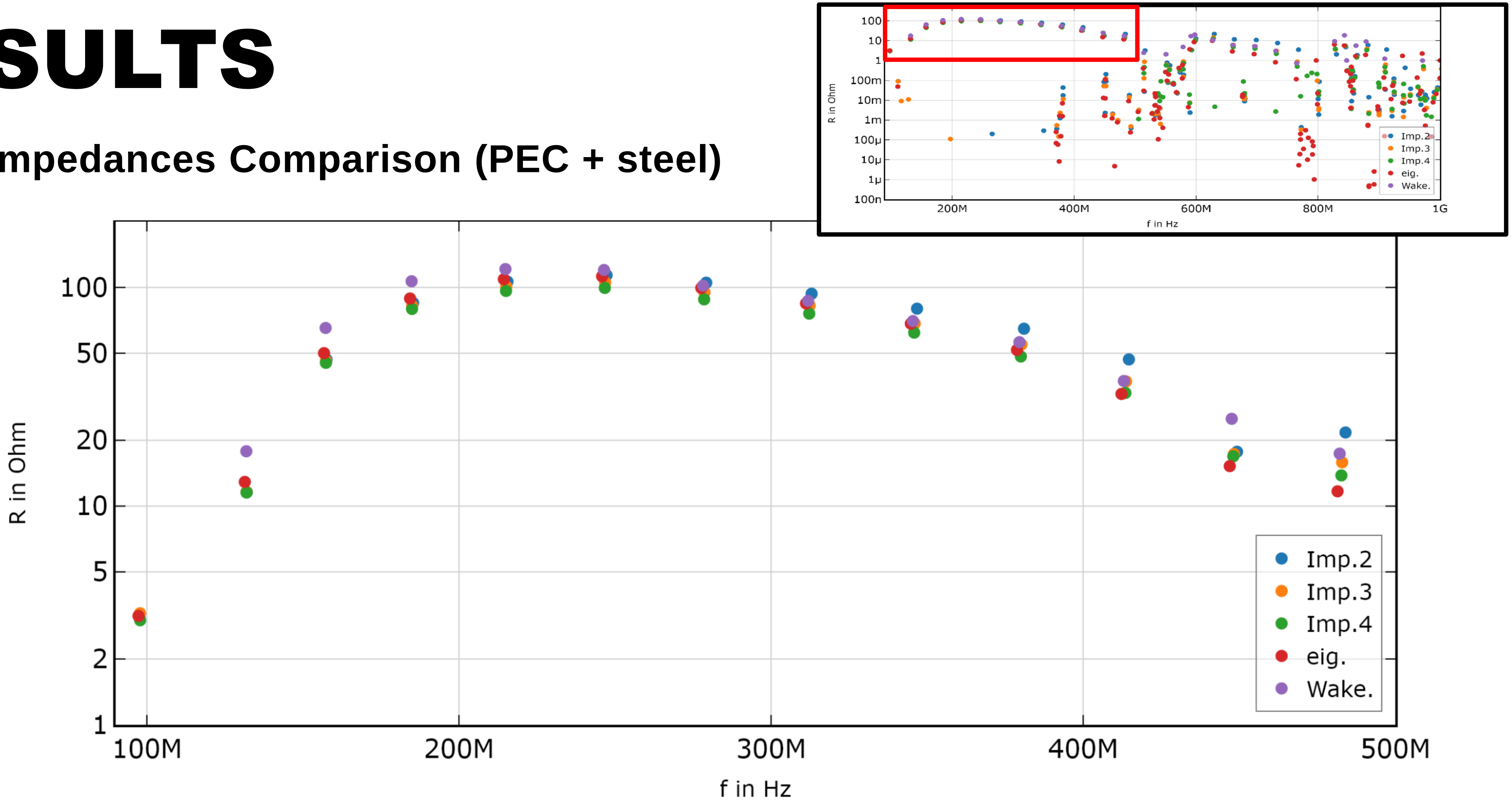

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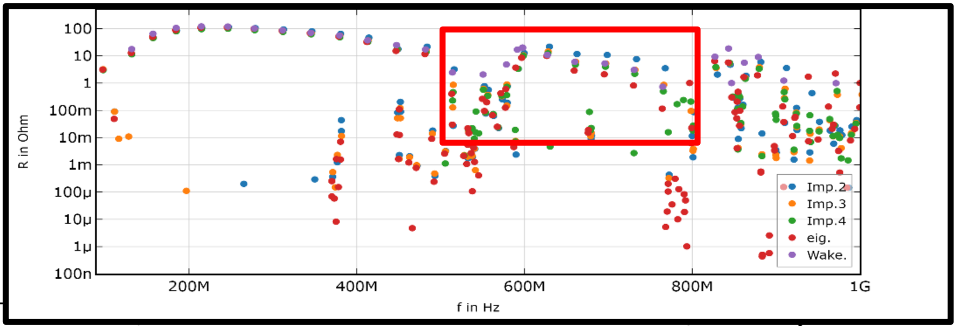

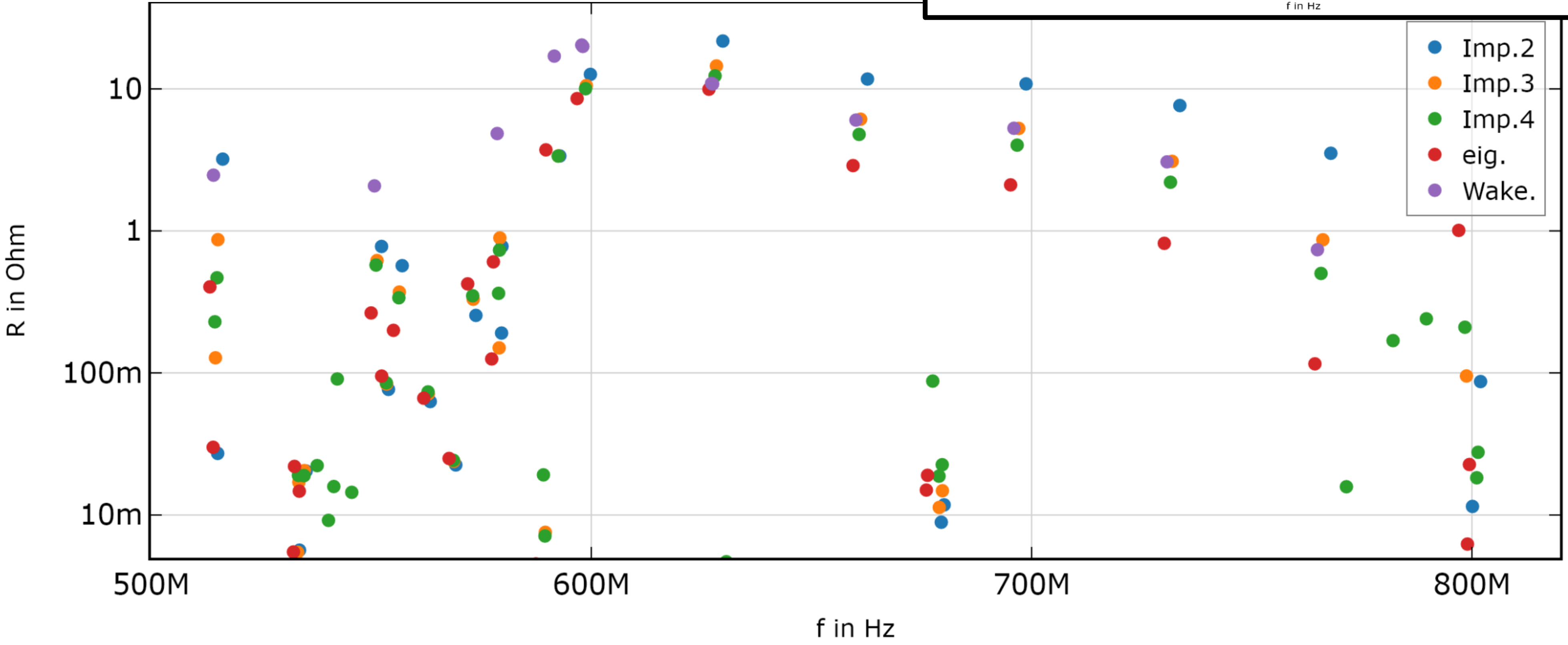

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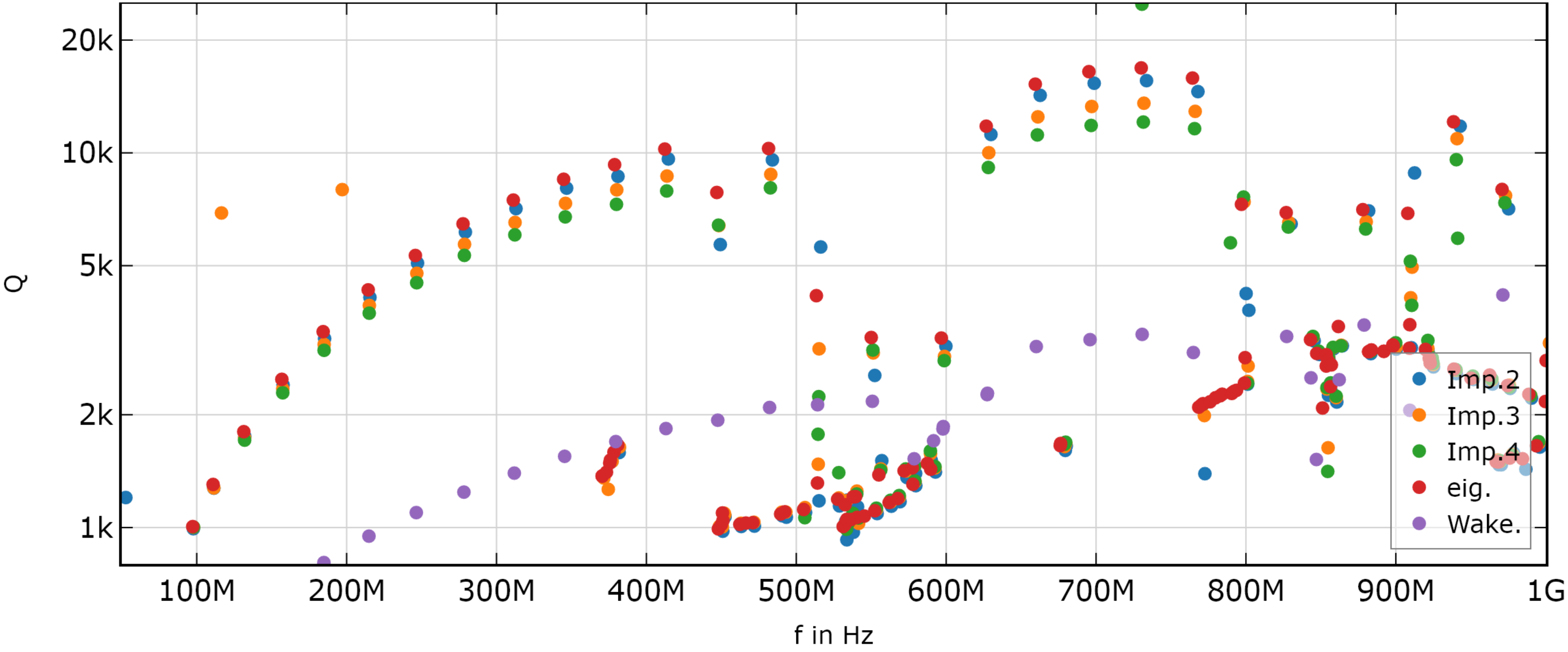
RESULTS

Q Comparison (PEC + steel)



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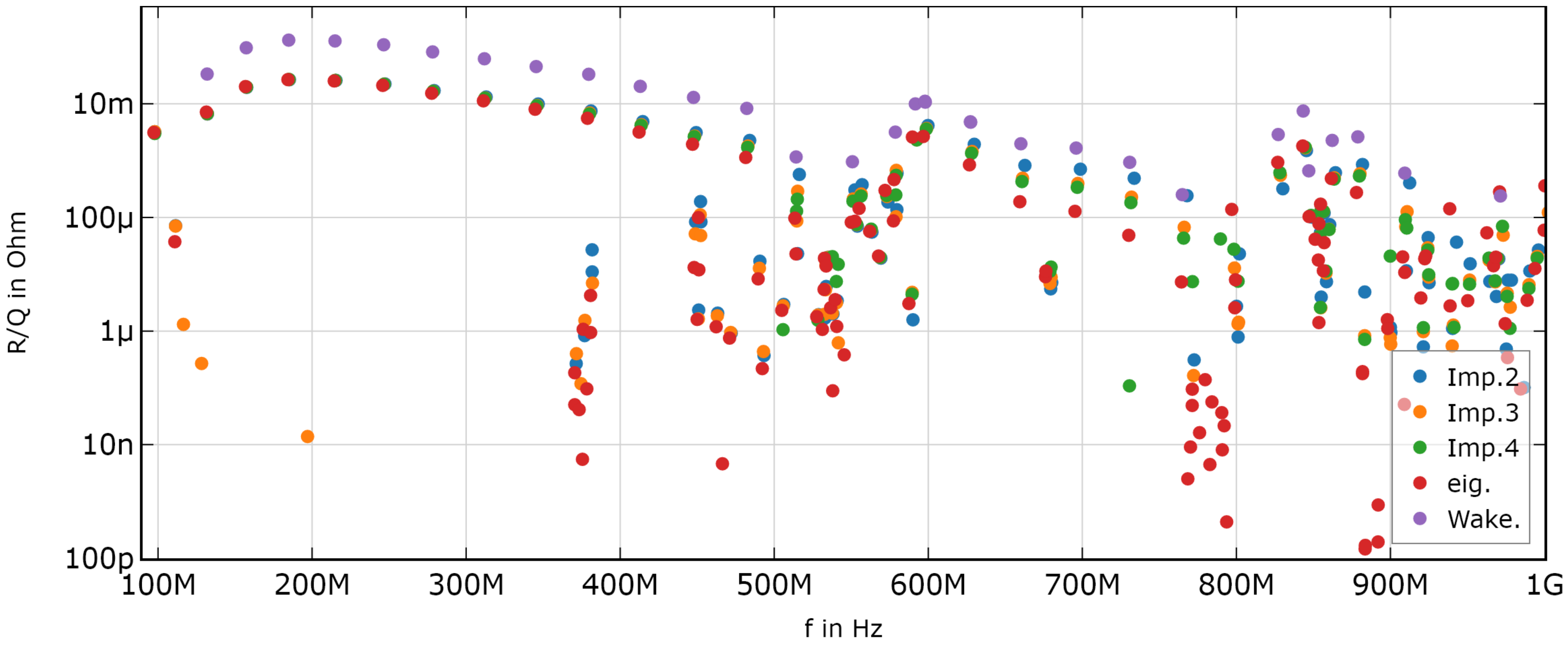
RESULTS

R/Q Comparison (PEC + steel)



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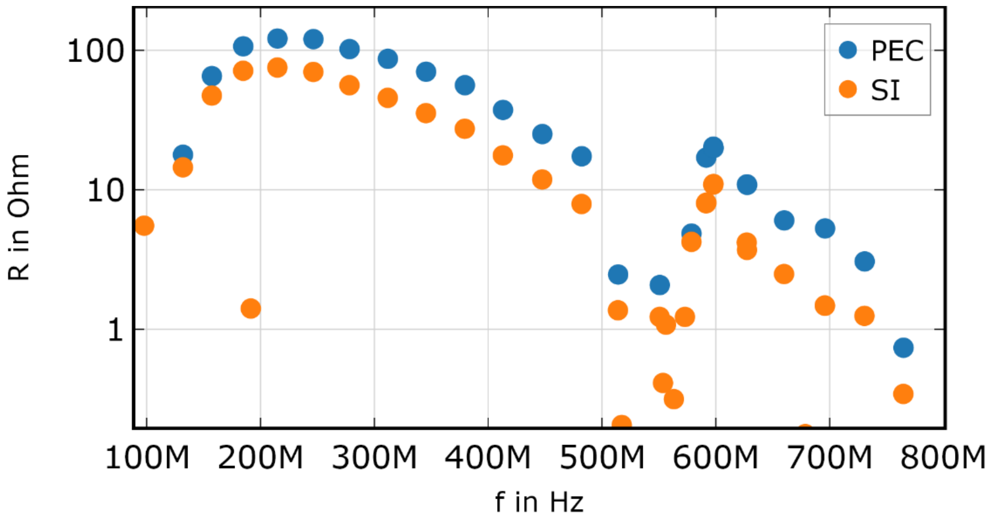
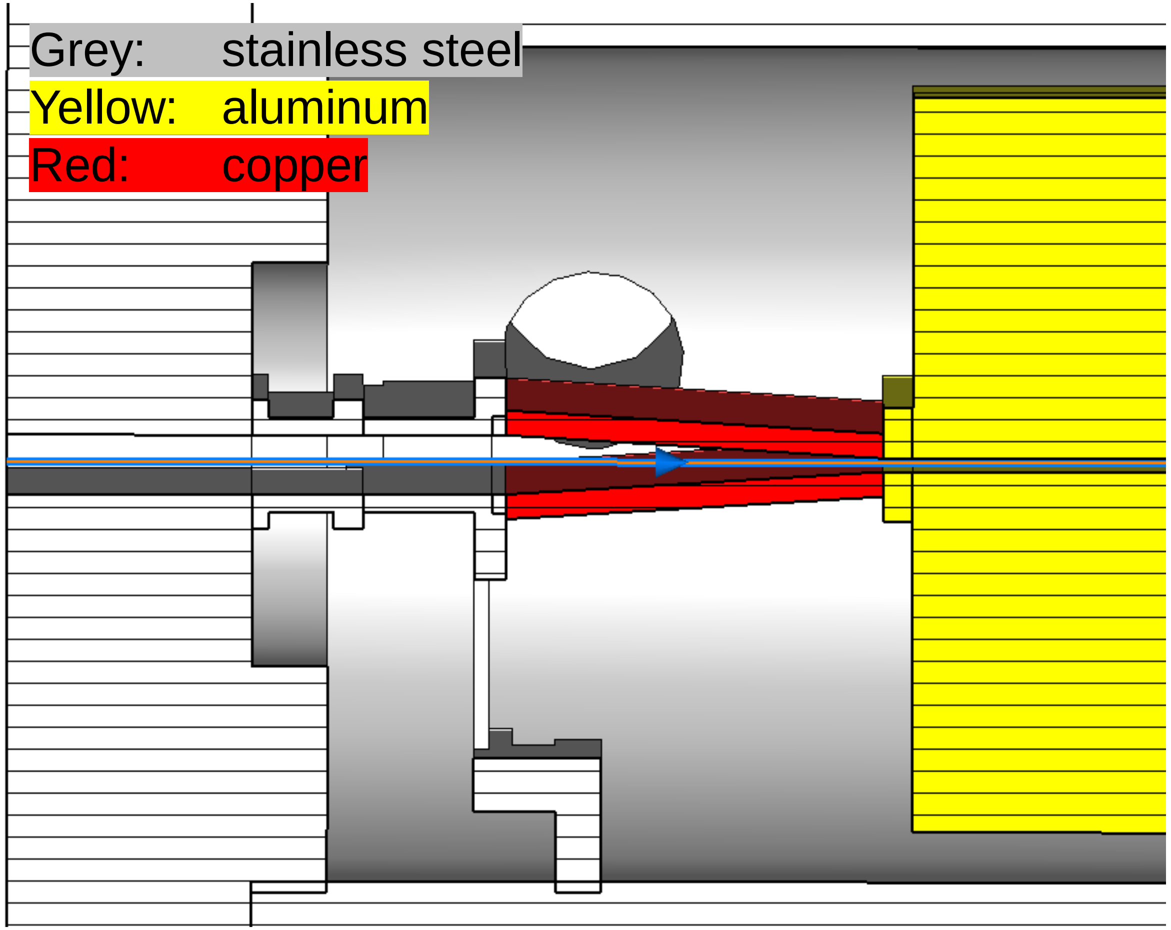
RESULTS

Effect of Materials on Zs

- CST Wakefield Solver





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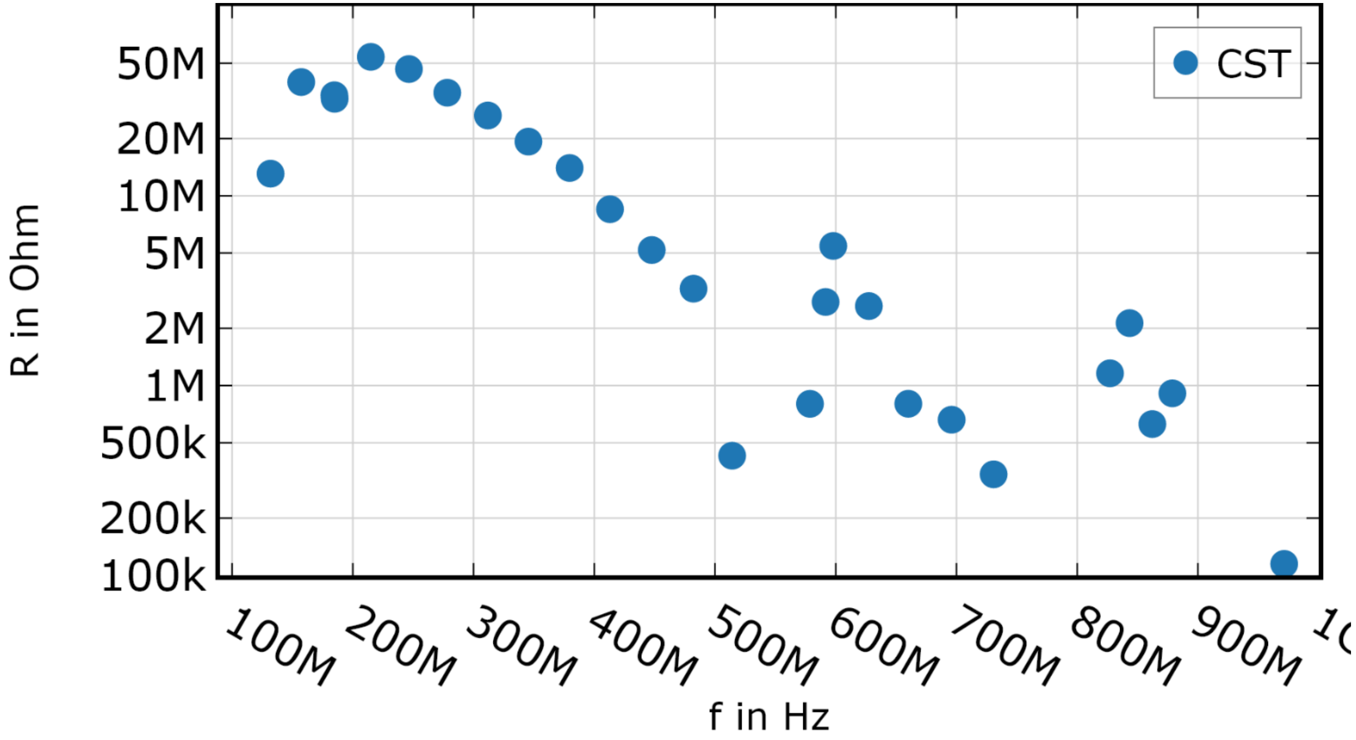
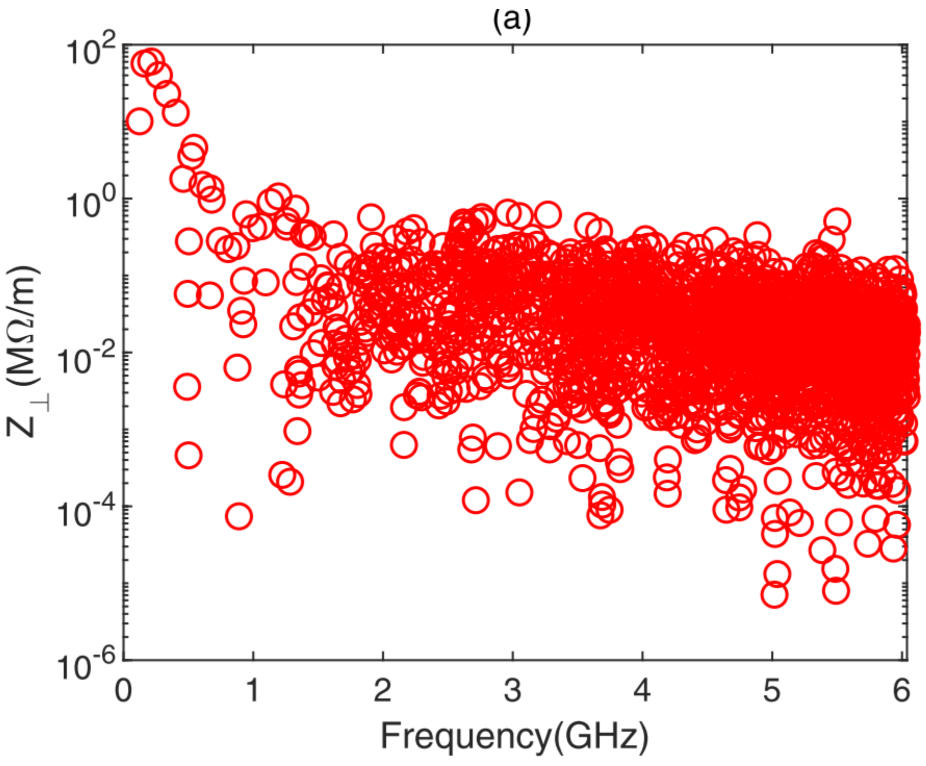
RESULTS

Transvere Shunt Impedances





Tian et. Al., PRAB 2019

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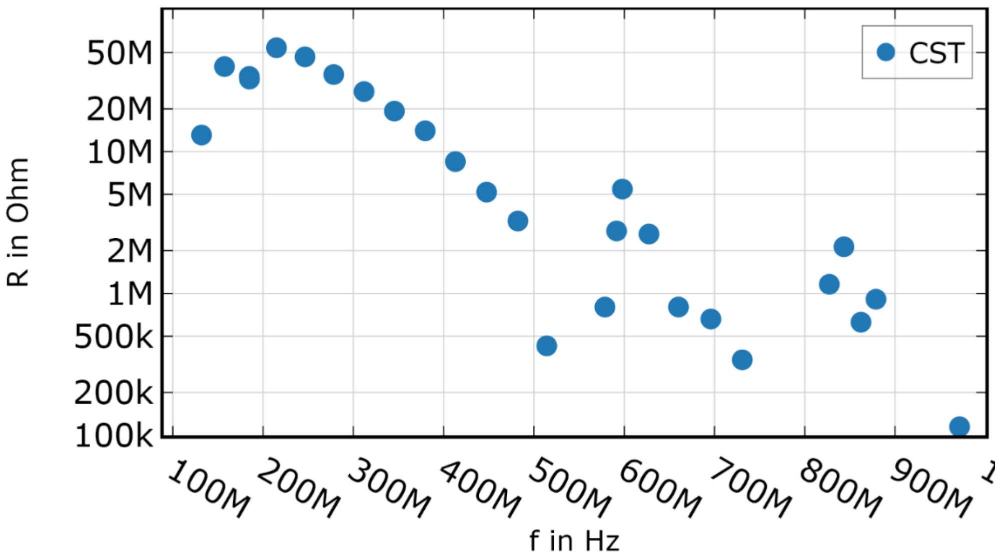
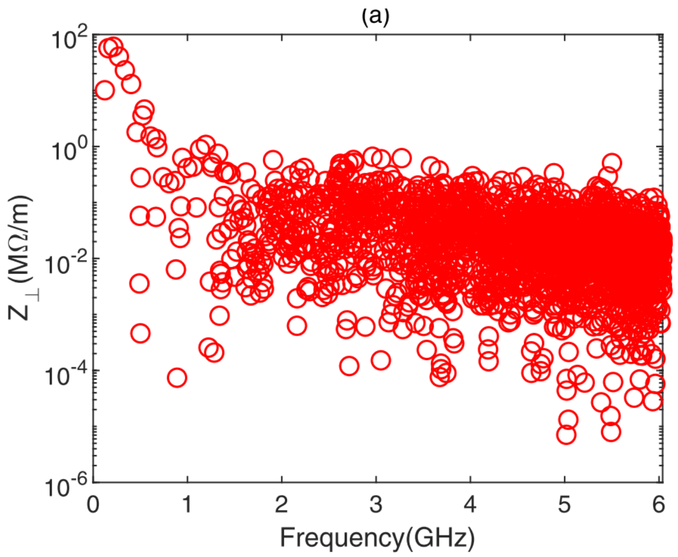
RESULTS

Transverse Shunt Impedances

- Similar mode pattern and magnitude
- Critical for stability: modes up to 300 MHz
- Damping scheme could be required (ferrites)





Tian et. Al., PRAB 2019

CONCLUSIONS

- Confident results up to 800MHz
  - f_0 (all three solver)
  - Shunt impedance (all three solver)
  - Q (eigenmode, impedance solvers)
  - R/Q (eigenmode, impedance solvers)
- Higher frequencies demand solver improvements
  - TD: geometry approximation, integration length
  - EM, FD: memory consumption
- Motivates development of advanced solvers

OUTLOOK

- Transverse shunt impedances
- Higher frequencies
- Geometry
  - Cooling
  - Flexible taper
  - Variable gap width
- Material properties
- Loss / cooling